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FISH BULLETIN No. 24

An Analysis of the Catch Statistics
of the Striped Bass (*Roccus line-
atus*) Fishery of California

By
J. A. CRAIG

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SACRAMENTO, 1930

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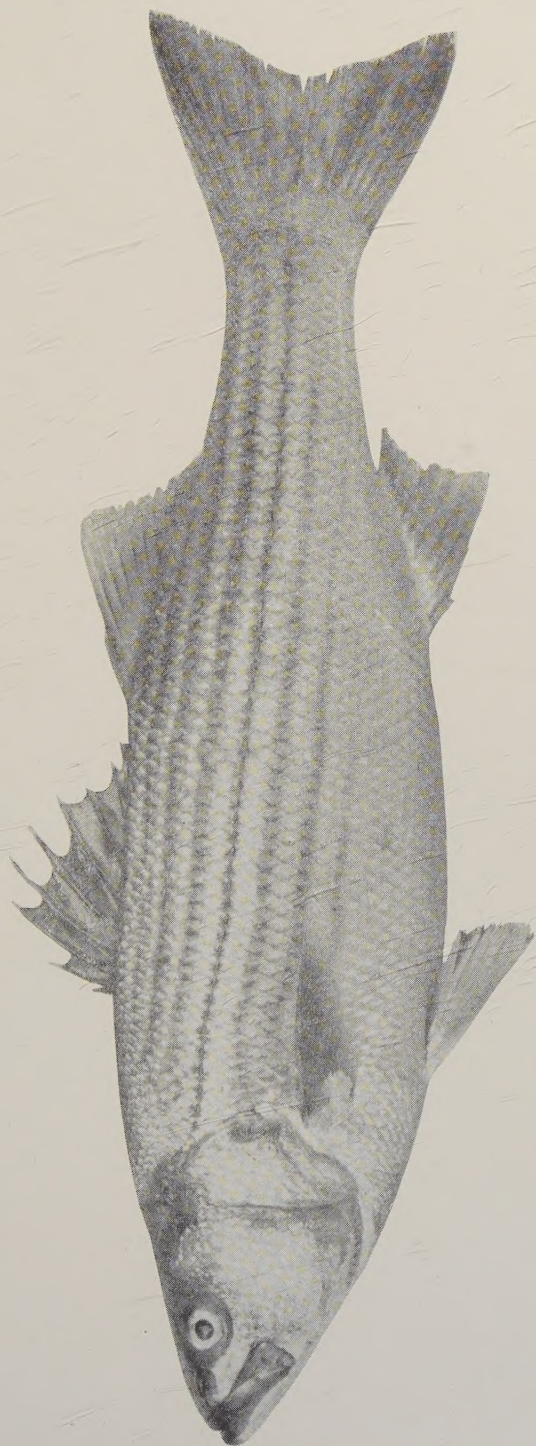
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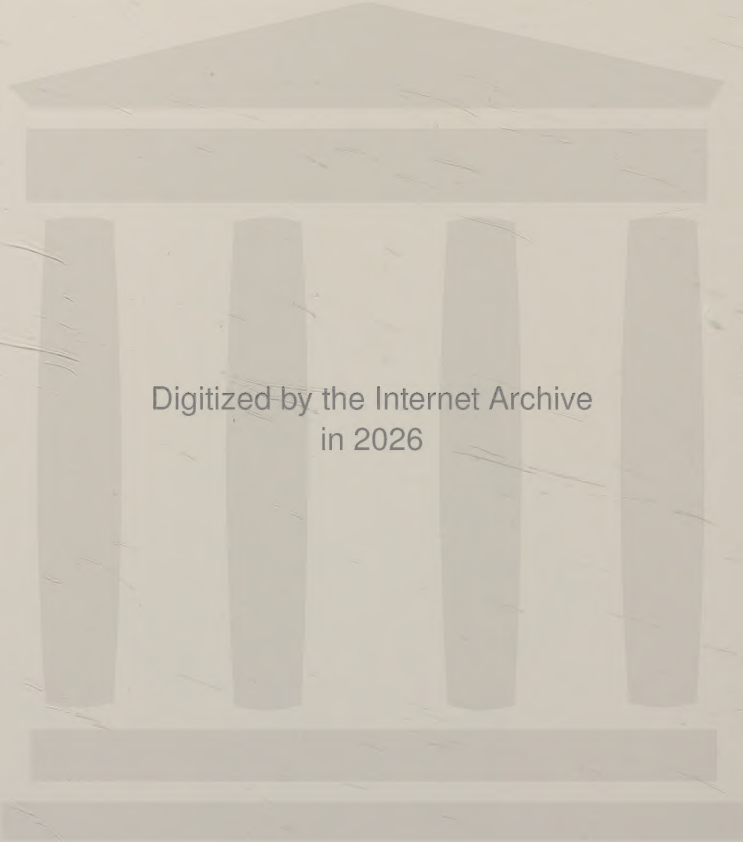
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Striped Bass (*Morone saxatilis*).

Photo by Gabriel Moulin.



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ACKNOWLEDGMENTS

The author wishes to express his appreciation to Dr. Willis H. Rich of the United States Bureau of Fisheries, Dr. Will F. Thompson, Director of Investigations of the International Fisheries Commission of United States and Canada, and Mr. W. C. Herrington on the staff of the same organization, and to Professor Holbrook Working of Stanford University, all of whom have been kind enough to confer at various times on problems connected with this publication. Mr. Norman B. Scofield, in charge of the Bureau of Commercial Fisheries of the Division of Fish and Game of California, and Mr. W. L. Scofield, Acting Director of the California State Fisheries Laboratory, aided in the preparation of this report by their cooperation and suggestions. Credit is also due to Miss Annie Gillespie of the California State Fisheries Laboratory, who drew most of the graphs herein presented.

An Analysis of the Catch Statistics of the Striped Bass (*Roccus lineatus*) Fishery of California¹

By J. A. CRAIG

PART I

INTRODUCTION AND DISCUSSION OF THE YEARLY TOTAL CATCH DATA

In order that the owners of a fishery or any other natural resource may derive the greatest benefit from that resource, it must be utilized to the fullest possible extent. A policy of unwarranted restriction or miserly hoarding does not give the maximum benefit to the owners, since they then are deprived of their legitimate profits. Nor does a program of wasteful extravagance produce the greatest possible good from a fishery. Indeed of the two courses the latter is the more unwise and harmful, since the resource may be reduced to such an extent that it is either obliterated or brought to a level so low that it can no longer produce profitable returns.

Therefore, the persons administering a fishery are confronted with the problem of getting the greatest possible returns from the resource, without harming the supply or breeding stock. There appears to be no method by which it is possible to determine how large a catch a fishery can produce without injury to itself, until depletion becomes apparent at least to a small extent. It would seem then that the only course remaining is to proceed to utilize cautiously the fishery, endeavoring to keep on the safe side so that depletion will not occur. Then if it is evident that the resource is being injured by over-production, either the supply must be increased artificially or the total take reduced.

Evidently then in conjunction with this method of trial and error, it is necessary to have some means of judging the point at which a state of injurious over-production is reached, in order that some remedy or regulation may be applied before the breeding stock of the fishery is depleted seriously. Probably the most common method in the past of judging the condition of a fishery has been to accept the opinions of people working or interested in the resource as evidence in the case. These opinions are usually of doubtful value, since depletion must proceed to an advanced stage before it becomes apparent to the casual observer, and it is then often too late to save the fishery. Also people deriving their sport or living from a fishery are apt to be prejudiced and their opinions biased or founded on a few observations of outstanding instances.

Figures showing the annual total catch of a species of fish are also often used as a basis for judging the relative abundance of a fish. When such data are used without careful analysis and other supplementary information, as is often the case, they are usually without value and often misleading.

¹ This manuscript was completed in virtually its present form in May, 1929.

This is necessarily so, because the abundance of a fish is only one of many factors which ordinarily cause fluctuations in the total take of that species. The total catch may remain constant or even increase while the species of fish is being depleted. Such a situation can be readily brought about by the effort expended on the fishery, number of men and boats, being increased, new and more productive fishing grounds being opened up, or a more effective type of gear coming into use. An increase in fishing effort may be caused by higher prices, failure of another fishery making it necessary for fishermen to change over to the one in question, or a greater demand offering opportunities for more men and boats.

Likewise a drop in total catch might occur when the supply of the species is holding its own or increasing. This may be caused by a decrease in fishing effort, legislation preventing use of effective gear or good fishing areas or fixing closed seasons, which diminish the available fishing time. Unfavorable weather or strikes of fishermen also may pull down the total catch for a brief time.

Therefore, since the total amount of any species taken in a calendar year is dependent on several factors other than the relative abundance of the species, namely: fishing effort, legislation, shifts in fishing grounds, weather, changes in another fishery, labor and economic conditions, some method of treating the catch figures, which will eliminate as nearly as possible factors other than abundance must be resorted to in order to secure any dependable index of abundance from the catch data. By expressing catch returns in some definite unit which is subject as little as possible to influence by factors other than abundance, such a desired result may be accomplished.

The catch return per a constant amount of fishing effort, gear and time, is such a unit. In other words the catch resulting from a constant amount of fishing gear and effort used for a constant period of time should be indicative of the relative abundance of a species of fish, or at least the availability of the species to the fishermen, providing the data used are representative samples of the catch results from the entire fishery. It is reasonable to assume that as a species of fish becomes less abundant, the same amount of gear employed in the same manner and for the same length of time will catch a lesser quantity of the fish as the supply decreases, or more fish as the supply increases.

However, all disturbing factors are not removed by using a constant unit of effort and time, since unfavorable weather or hydrographic conditions may diminish the catch artificially, new and more productive grounds may be opened up and cause a false rise in average catch, or good fishing territory may be closed by legislation and cause a drop in the average take per unit of effort and time. Also, there may be natural fluctuations in abundance caused by the appearance and gradual disappearance of dominant age groups, or migrations of the species to regions inaccessible or unknown to the fishermen.

Therefore, a curve showing catch returns per unit of effort and time should be correlated with all possible biological, economic and hydrographic data in order that it might be correctly interpreted as an index of abundance or availability of the species to the fishermen.

Before going into a detailed analysis of the catch statistics of the striped bass (*Roccus lineatus*), it may be well to review briefly the

history of this fish in the waters of California. Originally, this fish was a native of the Atlantic coast, but in 1879, 132 striped bass were collected in the Navesink River, New Jersey, and shipped to California. About 25 of the fish died in transit and the remainder was planted in the Straits of Carquinez, at Martinez. Three years later about 300 more were liberated in Suisun Bay at Army Point.

The success of these plantings was indeed phenomenal, as is indicated by the fact that as early as 1889, the United States Bureau of Fisheries reported a commercial catch of 16,296 pounds and in 1892 a total annual commercial catch of 56,209 pounds. The fish comprising the catch of 1892 were estimated to average about 10 pounds in weight.² Therefore the catch for the year 1892 contained about 5600 individuals. Since the abundance of striped bass has undoubtedly increased since that time, the original planting of less than 500 individuals, made 10 and 12 years before, was supplying an annual increase of more than

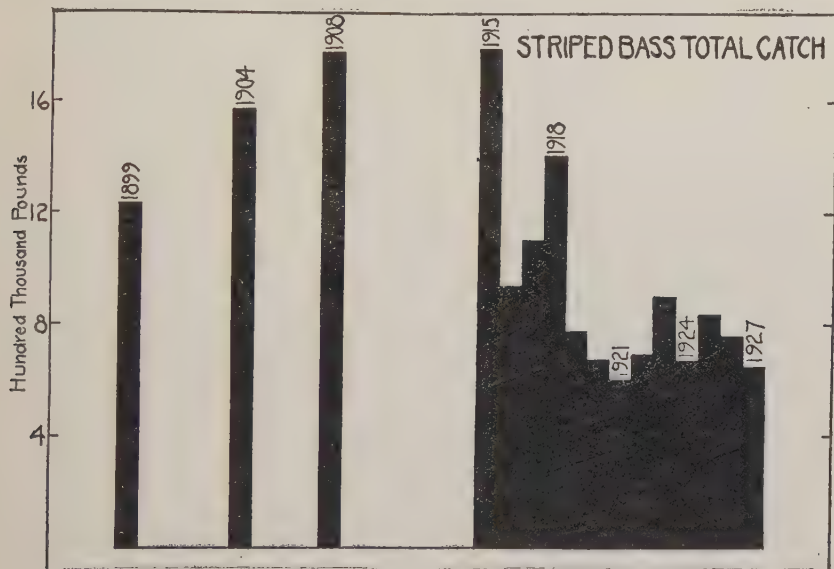


FIG. 1. Yearly total commercial catch of striped bass in California. The figures for 1899, 1904 and 1908 were compiled by the United States Bureau of Fisheries. From 1915 to 1927, inclusive, the data were compiled by the Division of Fish and Game of the Department of Natural Resources of California.

5600 fish in 1892. The new habitat into which the striped bass were introduced must be one extremely suitable to the fish, supplying them with abundant food, good spawning grounds and favorable temperature and hydrographic conditions.

Although total catch figures are sometimes a faulty and misleading criterion of abundance, when used unsupported by other evidence, at times they can yield a rough estimate of relative abundance of a species, if considered in conjunction with data relating to factors other than abundance, which may have caused fluctuations in the total annual catches. Fortunately, such data are available to aid in the

² Report of U. S. Commissioner of Fish and Fisheries, for 1893 (1895), page 151.

interpretation of the annual commercial catch totals for the striped bass in California. Therefore, it may be profitable to consider these catch data in conjunction with evidence of factors causing fluctuations in them.

Figure 1 shows graphically the total yearly catches for 1899, 1904, 1908, and 1915 to 1927, inclusive. The total yearly catch of striped bass reached the sum of 1, 234,320 pounds in 1899. The catch then rose to 1,570,404 in 1904, and 1,776,000 in 1908. The next yearly catch total available was 1915, which was 1,784,448. In 1916 there was a pronounced drop in total catch to 941,849 pounds. The catch of 1917 was of about the same magnitude, and 1918 showed a decided gain, totaling 1,407,841 pounds. From 1919 to 1927, inclusive, the yearly catch fluctuated without a great deal of variation around a mean of about 725,000 pounds.

If the total yearly catch figures were accepted as an index of the abundance of striped bass, one would be forced to conclude that the fishery has been seriously depleted from 1915 on to the present time. However, before drawing any conclusions regarding relative abundance from these data, possible causes for fluctuations in them other than depletion should be considered.

Variations in amount of fishing effort, number of men and boats and amount of gear, are among the most common causes of changes in the magnitude of yearly catch totals. Unfortunately no exact figures showing the quantity of gear and number of men and boats in the striped bass fishery for the various years are available. However, C. B. Tendick, statistical agent for the U. S. Bureau of Fisheries on the Pacific coast, estimates that in 1915 there were approximately 265 gasoline and 418 sail and row boats employed in the striped bass fishery of California, and in 1926 about 276 gasoline boats and only 4 sail and row boats. An increase of about 11 power boats and the almost complete loss of the fleet of over 400 sail and row boats is indicated by these figures. Although these values are merely estimates, there is small doubt but that there has been a decrease in number of men and boats participating in the fishery since 1915. This is doubtless one of the contributing causes to the decline of the total catch since 1915.

There were several reasons for the loss in number of men and sail boats from the striped bass fishery. The majority of the sail boats were remodeled and fitted with gasoline engines. Then during 1915 and the years immediately following, there was an extensive development of the fisheries of Monterey, chiefly salmon trolling and sardine fishing. This induced a large number of the fishermen to leave the bass, salmon and shad fisheries of San Francisco Bay and its tributaries, which is the only commercial fishing area for striped bass in the state, and move to Monterey. Also there was a great deal of restrictive legislation passed concerning striped bass fishing following 1915, and a number of fishermen probably abandoned their occupation and turned to more lucrative pursuits.

Unquestionably the chief cause of the drop in total catch from 1915 to 1919 was restrictive legislation. The first legislative measure protecting striped bass went into effect as early as 1893, when San Francisco County passed an ordinance prohibiting the sale of striped bass under eight pounds in weight. In 1895, a three-pound size limit was

made state-wide by the state legislature, and it also was made unlawful to take striped bass commercially between sunrise on Saturday and sunset of the following Sunday. Since that time at almost every legislative session there has been some added protection given the striped bass in the form of additional closed seasons, regulation of gear, or withdrawal of fishing areas from commercial fishing.

Some idea of the extent to which added closed seasons have lessened the number of legal fishing days can be gained from figure 2. In 1899, 1904, and 1908, the only closed days were the Saturdays and Sundays, which left about 261 days available to the fishermen. Then more closed seasons were added until in 1927 there were only 164 days during the year in which commercial fishing could be carried on legally. Therefore, in 1927 the number of legal fishing days was only 63 per cent of the days available to the fishermen in 1908.

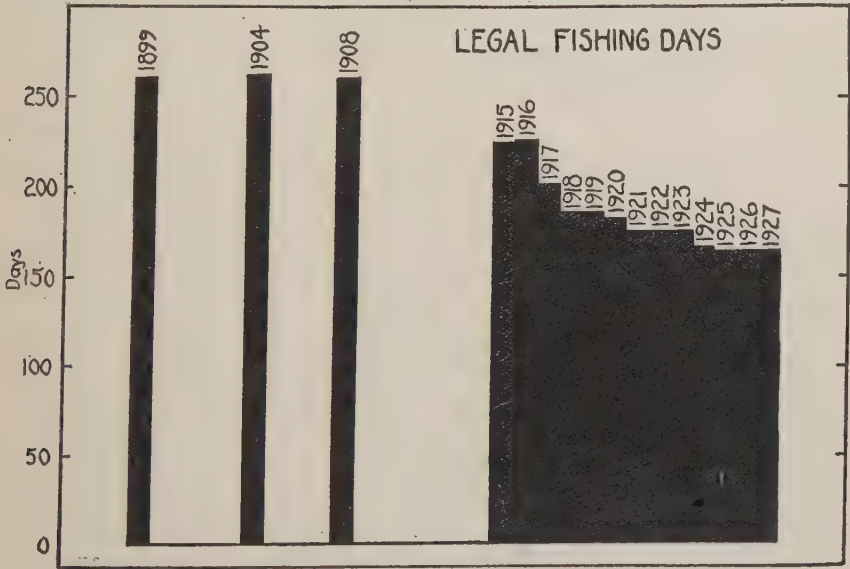


FIG. 2. Number of days in each year upon which commercial fishing for striped bass could be carried on legally in California.

This would tend to cut down the yearly catch, since a man can not be expected to catch as many fish in 164 days as he formerly did in 261 days. Also a large part of the closed days were taken from a portion of the year, May 16 to July 31, inclusive, when the bass are abundant on the fishing grounds and fishing conditions are usually good. Therefore, the effect of the closed season on the yearly catch would tend to be even more than the indicated loss of about one-third of the yearly fishing time.

Another series of legislative changes which have had a large influence on the yearly catches, are the measures prohibiting commercial fishing in many of the best fishing grounds. In 1911 it was declared unlawful to fish commercially in Cache Slough, Napa or Mokelumne rivers. In 1915 all commercial fishing was restricted to San Francisco Bay and the main channels of the Sacramento and San Joaquin rivers.

This made it unlawful for the commercial fishermen to utilize many square miles of the most productive fishing areas, and probably had more to do with the drop in yearly catches than any other single piece of legislation. In 1927 commercial fishing was prohibited in the greater portion of San Pablo Bay. This legislative act removed another choice area from the commercial fishing grounds.

Besides the two major restrictions of closed seasons and curtailment of fishing area, other less important protective measures, such as a closed season for commercial fishing for bass over ten pounds in weight between April 1 and May 31, and regulation of gear which may be used, have been passed by the state legislature, since the years when extremely high total catches were made.

It appears then that the drop in total catch of the striped bass does not indicate a decline in abundance of the species. It merely reflects the efficiency of the protective legislation passed, and the decline in fishing gear and effort which has taken place, and is the result that would be expected from these combined causes.

PART II

ANALYSIS OF DAILY CATCH RECORDS OF A SELECTED GROUP OF BOATS

Fortunately, detailed catch data have been collected by the Division of Fish and Game of California, which make possible an analysis of catch returns per unit of gear. From these, a more accurate and conclusive idea of the relative abundance of the striped bass may be obtained than can be secured from any analysis of the total catch figures.

These records are obtained as follows: All persons buying fish from fishermen are compelled by a state law to make out a triplicate receipt for the delivery at the time of the sale. These receipts show species of fish bought, price paid, weight of each species bought, name and custom house number of the boat delivering the fish, and the name of the fisherman selling the fish. The original copy is kept by the buyer, the duplicate is given to the fisherman selling the fish, and the triplicate copy is sent to the Bureau of Commercial Fisheries of the Division of Fish and Game, after which they are sorted and filed by boat in chronological order by that agency.

By means of these receipts, the Division of Fish and Game is enabled to keep a detailed record of all landings of all of the fishermen in California. In a fishery in which the boats engaged go out and return with their day's catch at the end of the same day, this becomes a record of the daily catches of the boats.

All fishermen are also compelled to register their boats each year with the Division of Fish and Game. On the registration cards is kept a record of the gear used in fishing during the year previous to registration. Any transfer of ownership is also indicated on this registration blank. From these two sources it was possible to obtain a record of the daily landings of a selected group of twenty boats, all of which had retained virtually the same gear and had not changed ownership during the period of time covered by the analysis, 1920 to 1927, inclusive. From these data a record was also taken of every alternate catch of all of the boats in the striped bass fishery.

Since practically all of the commercial fishing for striped bass in California is confined to San Francisco Bay and its tributaries, the fishermen are usually near some fish-buyer and are in most cases able to sell their fish shortly after making a day's catch. Many fish dealers also send out buyer boats to pick up the fish on the fishing grounds. Therefore, practically all of the day's catches, as reported on the buyer's receipts, represent the results of a day's fishing. Undoubtedly, there are occasions when fishermen are unable to return in time to dispose of the day's catch and add part or all of the following day's catch to their delivery. We believe this to be rather infrequent, and that in the amount of data handled this will occur approximately as often in one year as another, so that such adding together of catches will average about the same for each year.

Since no information is available as to the number of hours that gear is fished, the fishing day was taken in all of the following catch analyses as the unit of time. The time during each day when the gear is actually

being used varies from day to day. It seems logical to suppose, however, that the fishermen would make every effort to spend as much time fishing as is possible on each fishing day. This would cause each fishing day to approach the maximum possible fishing hours in each day, and when a large random sample is taken from the records of the fishing days, as was done in both series of data included in this paper, we believe that the average time for a day's fishing in various years will be very close to the same value.

In all of the following analyses, days when no catches were reported were disregarded. Days when no tickets were made out were not counted as days of zero catch, because there was no means of knowing whether or not any effort had been made to take fish on those days. In fact, it is certain that the instances when a boat goes out and makes an effort to catch fish and returns with no catch are not common, and here again we must depend on having a sufficiently large random sample so that the number of actual zero catches for any one year will average about the same as in the other years. It can safely be said that on practically all of the days when no catches were reported the boat did not fish because of bad weather, repairing nets, engine trouble, or any of a variety of causes. Since this is so, it is evident that any attempt to use the days when no report was made as zero catches would at once introduce a large error into the data.

Two separate samples were taken from the record of the daily catches of the striped bass fishermen. One sample included approximately one-half of all of the striped bass catches made during the period of time included in the analysis and will be more fully described in another section of this report.

The second group of data from the striped bass daily catch records was a selected sample composed of the records of the catches of twenty boats. The boats whose records were included were under the same ownership during the time covered by the analysis, and as far as could be determined by inspection of the registration records, they did not materially change their gear during that time.

Each of these boats with their gear and crews constitute a constant unit of fishing gear and personnel and the record of daily catches indicates the output of these constant units of gear and personnel over a constant unit of time. Practically all commercial fishing for striped bass in California is carried on by means of drift gill nets. Therefore, all of the data in both of these samples are the records of catches made by this type of gear.

The problem then is to combine the records of these separate units of fishing effort into annual or shorter seasonal averages or indices, indicating the relative output per unit of fishing effort during these periods of time. The average catch per boat per actual fishing day for each year is such a series of averages, which will yield values suitable for a comparison showing the relative success of the same fishing effort in the years for which data are available.

After tabulation of the data, it was evident that the catches of some of the boats were much larger than the catches of others. The average catch of the boat having the largest catches is over six times as great as the average catch of the boat having the smallest catches, during the years 1920 to 1927, inclusive. (See table 1.)

If the yearly averages were derived from the data in the original form, the boats having the larger catches would have the greater weight in determining the final result. For this reason the fluctuations in size of catch of the boats making the small catches would be obscured by the data from the boats bringing in large catches. This is not desirable, because variations in the catches of boats with habitually small catches should be as indicative of the availability of the fish to the fishermen as the fluctuations of the larger catches, provided that the small catches were as numerous and as uniformly distributed as the large catches.

Also, if for any reason a number of the boats contributing large catches ceased fishing or made few catches for a period of time, while the boats making small catches kept up their normal number of catches, the average catch would be smaller, due to the absence of the normal number of large catches. Such a drop in the average catch would not be indicative of any change in the availability or abundance of fish, and would therefore introduce an error into the computations.

In order to correct the data for such an error, or at least guard against it, the catches of all boats were raised to an equal magnitude with the catches of the boat having the largest average catch per fishing day during the eight years covered by the data.

TABLE 1
Average Catch in Pounds Per Fishing Day During 1920-1927, Inclusive

Boat	1	2	3	4	5	6	7	8	9	10
Average.....	70.38	18.30	20.49	110.43	43.70	43.84	91.54	54.00	114.45	96.85
Boat	11	12	13	14	15	16	17	18	19	20
Average.....	120.98	37.56	91.23	84.78	97.19	56.66	45.11	21.80	46.91	95.27

This was accomplished by the following procedure: The average daily catch of each boat during the eight years was determined. (See table 1.) This was done by summing up all of the catches made by each boat during the eight years and dividing the total so obtained by the number of catches constituting that sum.

A factor was then computed for the catches of each boat. The boat having the largest average daily catch, number 11, with an average catch of 120.98 pounds, was given arbitrarily a factor of 1.00. The factors for the other boats then were computed, using the 120.98 as a base or unity. The average catch of the boat having the factor 1.00 was divided by the average catch of each of the other boats in turn, the result of each of these divisions giving the factor of each respective boat.

As for example, boat number 2 made catches averaging 18.30 pounds during the eight-year period. The factor for that boat was then $\frac{120.98}{18.30}$ or 6.61. Factors for each boat were computed in that way. (See table 2.)

From the first tabulation of catch records the catches of each boat were summed up in approximately half-month periods. These periods, which included all of the legal fishing days in one year, were numbered

from 1 to 15, inclusive. The dates corresponding to the numbered periods were as indicated in table 3.

Approximately fifteen-day or half-month periods were selected as a short time unit because this was about the shortest unit of time into which the data could be divided and still have enough catches falling in each separate unit to constitute a significant sample. Also it appeared that units of about fifteen days were small enough to give detailed information on any short time seasonal fluctuations that might have taken place. The half-month periods also make the task of dividing the data simple, since all of the opening and closing dates of the legal open seasons fall on about the first or middle of some month.

After the catches of each individual boat were summed up in fifteen-day periods, each of the totals was multiplied by the factor for that boat and the results of the multiplications and number of catches con-

TABLE 2
Computed Factors for Each Boat

Boat	1	2	3	4	5	6	7	8	9	10
Factor.....	1.72	6.61	5.90	1.10	2.77	2.76	1.32	2.24	1.06	1.25

Boat	11	12	13	14	15	16	17	18	19	20
Factor.....	1.00	3.22	1.33	1.43	1.24	2.14	2.68	5.55	2.58	1.27

TABLE 3
Period Numbers with Corresponding Dates
(All dates inclusive)

Period number	Date	Period number	Date	Period number	Date
1	January 1-15	6	March 16-31	11	August 16-31
2	January 16-31	7	April 1-15	12	September 1-16
3	February 1-15	8	April 16-30	13	November 15-30
4	February 16-28 or 29	9	May 1-16	14	December 1-15
5	March 1-15	10	August 1-15	15	December 16-31

stituting the totals were recorded. The products of these multiplications are then total catches of each boat for approximately fifteen-day periods multiplied by factors, which raise the catches of all boats to an equal average magnitude with the boat which had the largest average daily catch of all of the group of twenty boats.

Since the catches of all of the boats were on equal basis, it was possible to combine the individual boats into averages of the entire group of twenty boats, with each boat having an equal weight in determining these averages, as far as size of catch would influence the final results. The catches of the individual boats were combined into the composite averages of the entire group as follows: First, the total catches of all of the boats for each period in each year were determined after they had been multiplied by their respective factors. The number of catches made by all of the twenty boats in each period in each year was then computed by adding together the number of catches made by the individual boats during those periods of time.

The average catch per boat per fishing day for each period in each year was then computed by dividing the total catch of all of the boats in each period in each year by the corresponding number of catches.

The average catch per boat per fishing day during each year was determined. This was accomplished by adding together the total catches of all of the periods in each year and obtaining the sum of the number of catches constituting those totals, and dividing each total yearly catch so obtained by the number of catches made in each respective year.

The values obtained above represent the average catch per fishing day of a constant unit of fishing gear and personnel during each of the years indicated, 1920 to 1927, inclusive.

These same yearly averages can be derived by a shorter and more simple method. This was done as an illustration of the more simple procedure, which can be used when only yearly averages are desired. The total yearly catch of each boat with the corresponding number of catches have been calculated. The factor for each boat has also been given. The yearly total catches of each boat were multiplied by their respective factors. The result of this operation was the yearly catches of all boats raised to an equal basis with the boat having the largest catches. From this point on, all catch totals considered in this sample of data will have been multiplied by their respective factors.

TABLE 4

Year	1920	1921	1922	1923	1924	1925	1926	1927
Average catch per fishing day, in pounds.....	93	118	124	142	100	135	137	113
Number of catches included in averages.....	664	690	770	872	864	965	774	948

The total yearly catches of all of the boats were added together in each year. The number of catches of all of the boats in each year was also computed by adding together the number of catches of the individual boats in the respective years. The average catch per fishing day per boat in each year was then found by dividing each year's total catch of all of the boats by the number of catches included in that total.

The values in table 4 and figure 3 represent the average catch per actual fishing day per boat during each calendar year indicated, the catches of all boats being given equal weight in determining the result. A correction can now be made on these values. There is considerable variation in the average size of catch of the fifteen-day periods into which the data for each calendar year have been divided. This is graphically shown in figure 4, which indicates the arithmetic mean of the catches in each fifteen-day period during the eight years included in the data. The values there graphed are shown in table 5. These averages were obtained by adding together the sums of all of the catches occurring in each respective period during the eight years, adding together the corresponding numbers of catches, and dividing the sum of the catches occurring in each period during the eight years by the number of catches represented in the respective sums.

From table 5, it can be seen that the average catch per boat per day during each period ranges from 74 pounds to 187 pounds. Evidently

then there is a marked seasonal fluctuation in the size of the average catch per boat per fishing day, with the lowest point from March 16 to 31, and the maximum catches occurring from November 15 to 30. Since this is so, the years having above-average catches during the seasons of normally large catches will have a larger arithmetic mean than years showing an equal percentage excess over normal in the seasons of low catches. This is due to the fact that equal proportional increases among large and small numbers necessitate a larger gain in actual value for the large numbers. These greater increases in the large numbers will add more to the total than the lesser gains of the small numbers, and since the number of items is not changed, the year having the greater total will also have the greater average catch.

Also years having a greater than usual number of catches falling in the seasons of large catches will tend to have a larger arithmetic mean than years having a normal or less than normal number of catches in the periods of large catches. Conversely, a year having more than the average number of catches in the seasons of low catches will have its mean lowered, even though these low catches be above the normal catch for that season of the year.

Such errors can be guarded against by determining the percentage deviation for each period as compared to the corresponding period of

TABLE 5

Period	1	2	3	4	5	6	7	8
Average catch, in pounds.....	132	124	112	106	96	74	91	129

Period	9	10	11	12	13	14	15
Average catch, in pounds.....	141	170	125	127	187	100	139

a base or standard year, and then averaging the increases and decreases of all of the periods in each year. This was done as follows: The average catch per boat per fishing day for each fifteen-day period during the eight years covered by the data, as shown in figure 4 and table 5, was used as the standard of comparison. The average catch per boat per fishing day in each fifteen-day period in each year was then computed by adding all of the catches of all boats occurring in each period in each year, recording the corresponding number of catches and dividing the total catch for each period so obtained by the number of catches included in each total.

The values for each period in the standard year were changed to logarithms, as were the values of the average catch per boat per fishing day in each period in each of the individual years. The logarithmic values for each period in the standard year were subtracted from the logarithmic values of each of the corresponding periods in all of the years represented in the data. These logarithmic differences between each period in each year and the corresponding period in the standard year were then tabulated by years.

The average logarithmic increases or decreases in each year were then computed by weighting each period according to the number of catches occurring in the period, summing up the differences, and divid-

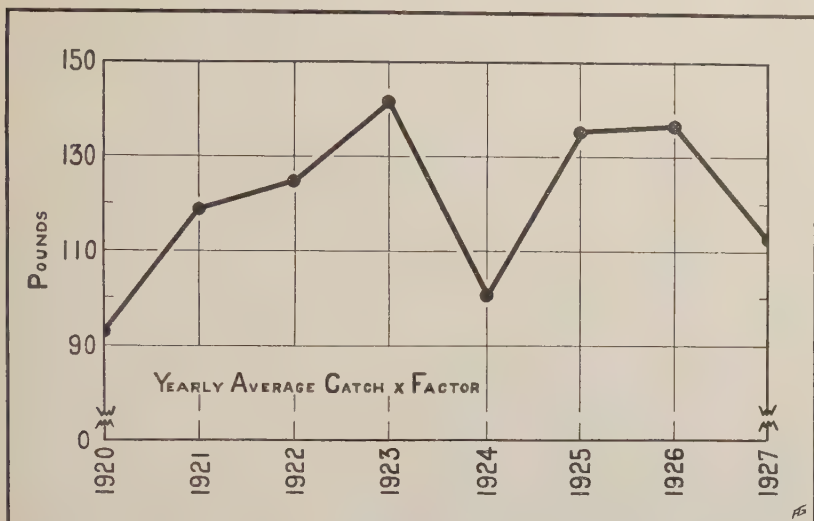


FIG. 3. Average catch per boat per fishing day during each year indicated, after multiplication by factors.

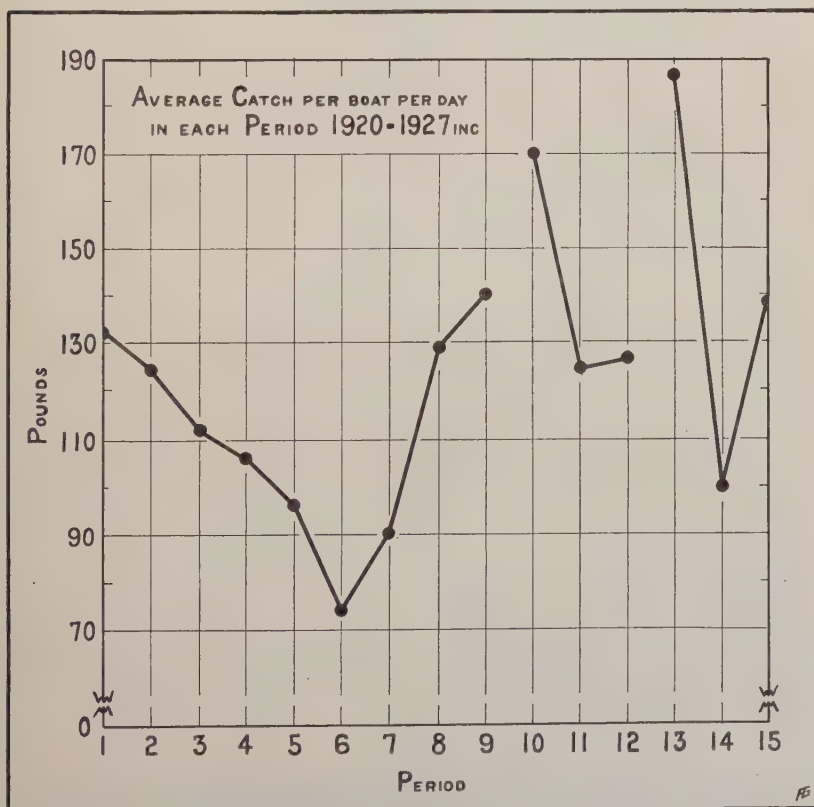


FIG. 4. Average catch per boat per fishing day of 20 selected boats during each period. Data from 1920 to 1927, inclusive.

ing each yearly total by the number of catches made in that respective year. The logarithmic averages resulting from this procedure were then changed to antilogarithms and multiplied by one hundred, the resulting percentages indicating the percentage that each year was of the standard year, when like seasonal parts were compared.

When the logarithms of the fifteen-day periods of the standard year were subtracted from the logarithms of the corresponding periods in each of the other years, the result was the logarithm of the proportional increase or decrease of each period as compared to the corresponding period in the base year. If the logarithms resulting were changed to antilogarithms and multiplied by one hundred, the result would be analogous to those obtained by determining what percentage each period in each year is of the corresponding standard period.

These percentages could then be weighted and averaged as was done with the logarithmic differences for each year. However, by changing the values concerned to logarithms and having them in that form until the final step, the labor necessary to perform the computations is materially diminished. Also when the logarithms of increase and decrease are averaged, the yearly averages resulting are the geometric means of the increases and decreases of each year, and since it is generally accepted that the geometric mean is the correct measure of central tendency to be used when computing average rates of increase

TABLE 6

Year	1920	1921	1922	1923	1924	1925	1926	1927
Average percentage deviation from standard year.....	74	92	93	114	76	94	121	84

or decrease, this procedure seems to be the most sound mathematically, as well as the one involving the least labor.

The results of the above computations are shown in table 6 and graphically represented in figure 5.

Also the differences in trend between the average daily catch per boat per fishing day as shown in figure 3 and the average increase or decrease in average daily catch per boat per fishing day during each year as compared to corresponding seasonal parts of a standard year are shown in figure 6. The chief differences between the two curves appear to be in the positions of the values found for the years 1925 and 1926. In the simple arithmetic curve first obtained, the yearly average for 1925 is almost as high as 1926 and closely approaches that of 1923, while that of 1926 is lower than that of 1923; the value for 1923 being 142 pounds as compared to 135 pounds for 1925 and 137 for 1926.

However, in the curve presented in figure 5 showing the average increase or decrease of each year as compared to corresponding seasons of the standard year, 1925 with 94 per cent is considerably lower than 1923 with 114 per cent, or 1926 with 121 per cent. Also 1926 has a higher value than 1923, reversing their positions in the preceding curve.

These differences in relationship are due to the lower relative value found for 1925 and the higher value for 1926 in the second method presented. The reason for the lower value for 1925 can be seen by referring to figure 7, which shows graphically the average catch per

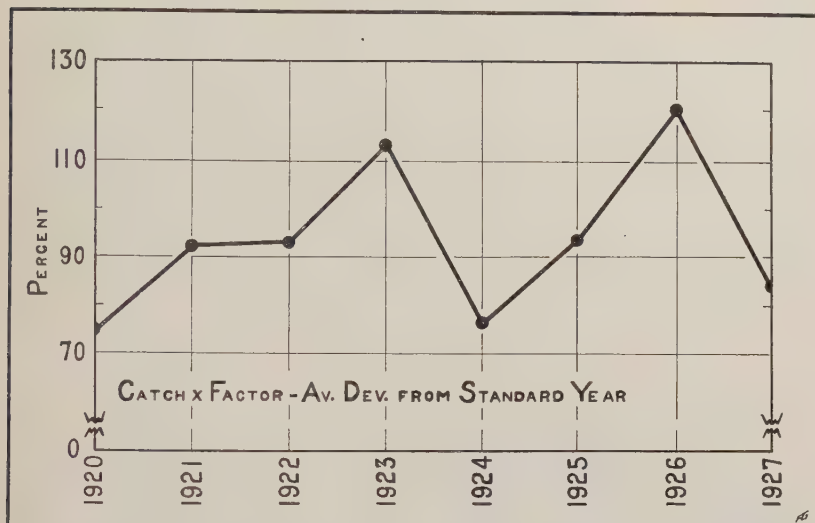


FIG. 5. Average percentage deviation of all years when the average catch per fishing day in each period in each year is compared to the corresponding values in the standard year.

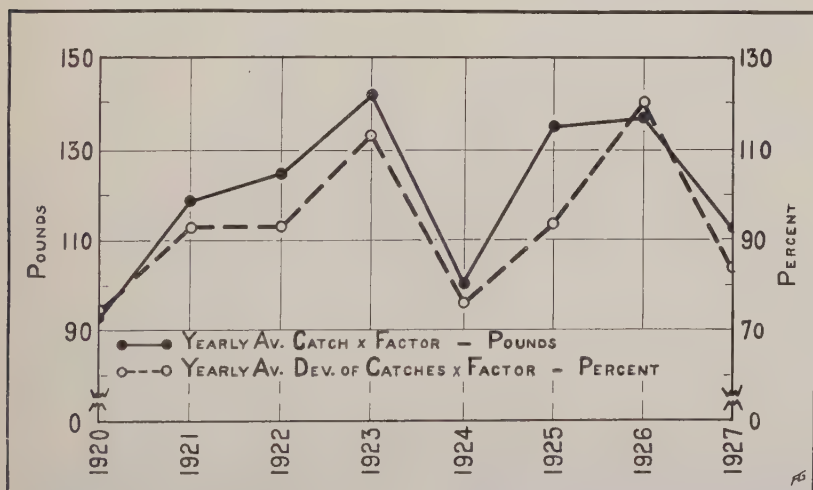


FIG. 6. Yearly average catch per boat per fishing day after multiplication by factors, compared to yearly average deviations from standard year.

day per boat in each of the half-month periods both for 1925 and for the standard year. It will be observed that during 1925, the catches were consistently low during the first nine periods of the year when the catches, as shown by the standard year, are normally low. However, 1925 showed remarkably high catches during the last six periods, with the exception of one period, when the catches are normally higher than during the first part of the year. Therefore, since the catches of greater than normal size which were made in 1925 occurred during the season of normally large catches, and the catches of less than normal size occurred during the season when the catches are ordinarily small, the proportional increase of the year over the average year is less than the increase of the average daily boat catch in actual pounds.

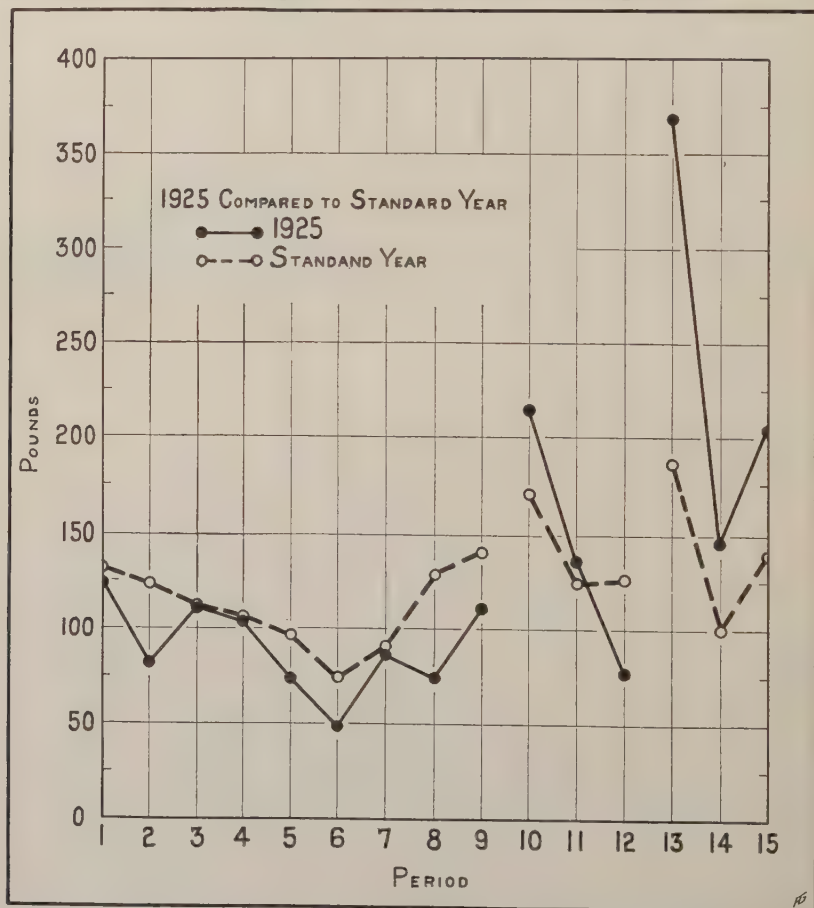


FIG. 7. Average catch per boat per fishing day during each period in 1925, compared to same values of the standard year.

During the year 1926, the opposite of this situation was true. In figure 8, it may be seen that during 1926 the catches were above average size during the first part of the year, when the small catches are normally made. In the later part of the year, when the large catches are made, the catches for 1926 were below average with the exception

of one period. This is the reverse of the case of 1925 and the average seasonal proportional increase of the year as compared to the standard year gives 1926 a higher position in relation to the other years than does the actual average catch per boat per day.

The corrected curve appearing in figure 5 appears to be the best yearly index of the abundance or availability to the fishermen of the striped bass of San Francisco Bay and its tributaries that can be compiled from the data supplied by the twenty selected boats, which have been discussed up to this point. These results will now be compared to those obtained by analyzing a second group of data from the same fishery and location.

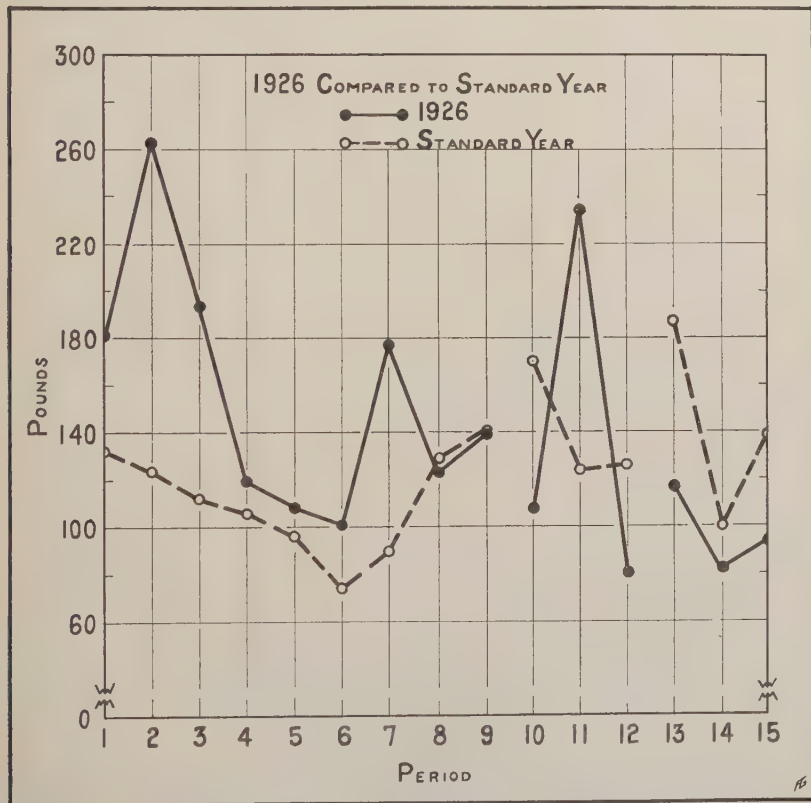


FIG. 8. Average catch per boat per fishing day during each period in 1926, compared to same values of the standard year.

PART III

ANALYSIS OF A RANDOM SAMPLE OF DAILY CATCH RECORDS OF THE ENTIRE FISHERY

These additional data were compiled from the catch records of all fishermen making striped bass catches on the Sacramento-San Joaquin rivers and San Francisco Bay, and consisted of a random sample of approximately one-half of all of the striped bass catches made in that area. The sample was taken by tabulating from the original catch receipts every other daily catch of each fisherman. By following that procedure, one-half of each man's daily catches was recorded in chronological order.

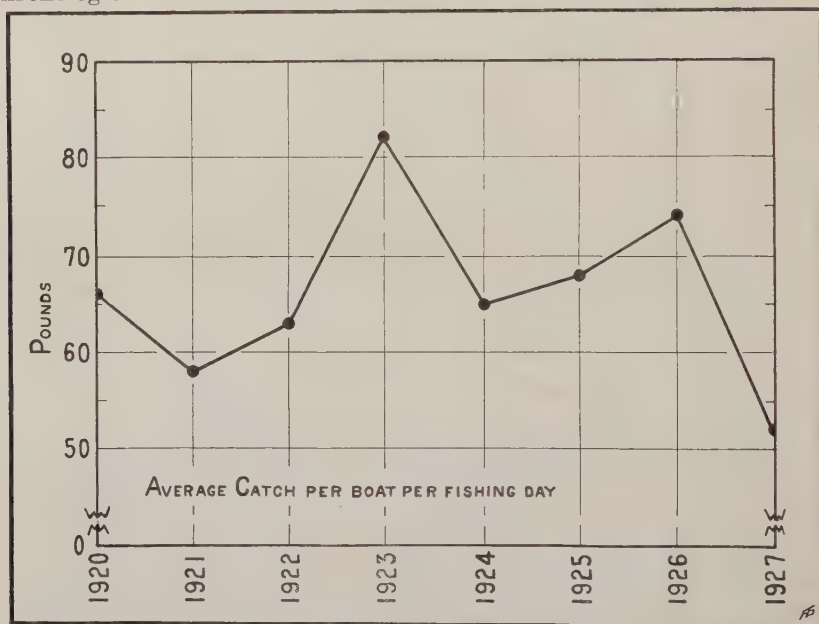


FIG. 9. Average catch per boat per fishing day during each year indicated, computed from the random sample of catch data.

The data were then retabulated by half-month periods, so that all individual catches falling in the same half-month were recorded in the same group. The sum of all catches falling in each half-month group was then determined and the number of catches made in the respective groups recorded. From these sums, the average catch per boat per day during each half-month period was calculated by the process of dividing the total catch for each period by the number of catches made in that period. This procedure was followed for each semi-monthly period. The average catch per fishing day per boat during each year was then calculated by the procedure of summing up all of the catches made during each year and dividing the sum by the number of catches recorded for that year. The results of these computations are shown in table 7. Figure 9 shows these yearly averages graphically. The values indicated in this graph show the average catch per boat

per day actually fished during each year represented, the average being computed from a random sample of approximately one-half of all the catches made by all of the boats engaged in the striped bass fishery of San Francisco Bay and its tributaries.

The index of abundance of striped bass presented above was then corrected in order to produce the most logical and correct result.

A correction for differences in size or fishing ability of the various boats such as was accomplished by the use of factors, which raised all boats to a common mean, was not possible or needed in dealing with the data now under consideration, and which consist of a random sample from the catches of all of the boats in the entire fishery. To determine the average catch of each boat involved, compute a factor for each boat and raise the catches of all the boats to a common mean would involve an immense amount of labor. Also it would not be necessary. In such a large random sample in which catches from all of the boats in the fishery are included in each year, it seems logical to suppose that in no single year will all of the boats habitually making either large or small catches have an extraordinarily large number of catches

TABLE 7

Year	1920	1921	1922	1923	1924	1925	1926	1927
Average catch per fishing day, in pounds.....	66	58	63	82	65	68	74	2
Number of catches included in averages.....	4,484	4,561	4,489	4,643	4,755	5,376	4,626	5,906

TABLE 8

Period	1	2	3	4	5	6	7	8
Average catch per fishing day, in pounds.....	70	60	61	62	59	50	48	58

Period	9	10	11	12	13	14	15
Average catch per fishing day, in pounds.....	59	126	85	101	97	65	72

and so cause an error. In short the adequacy of the sample is deemed such that a constant boat size and fishing ability have been obtained in all of the years presented.

However, it appeared advisable to correct this curve by making comparisons of parts of each year to corresponding seasonal parts of a standard year. As with the preceding data, this was done for the purpose of guarding against the possibility of some years having either all of their above-normal catches in the seasons of high catches or an unusual amount of catches during the seasons of high catches, and so having a yearly average erroneously high in comparison to years which had above-normal catches in seasons of small catches or few catches during the periods of large catches.

The method used in accomplishing this was the same as that followed with the preceding data. The data for each year were divided into approximately half-month periods, corresponding to the periods used in the first analysis in number and date. A base or standard year was then computed by determining the arithmetic mean of the catch per fishing day in each period during the eight years included in these data. These results are presented in table 8 and figure 10.

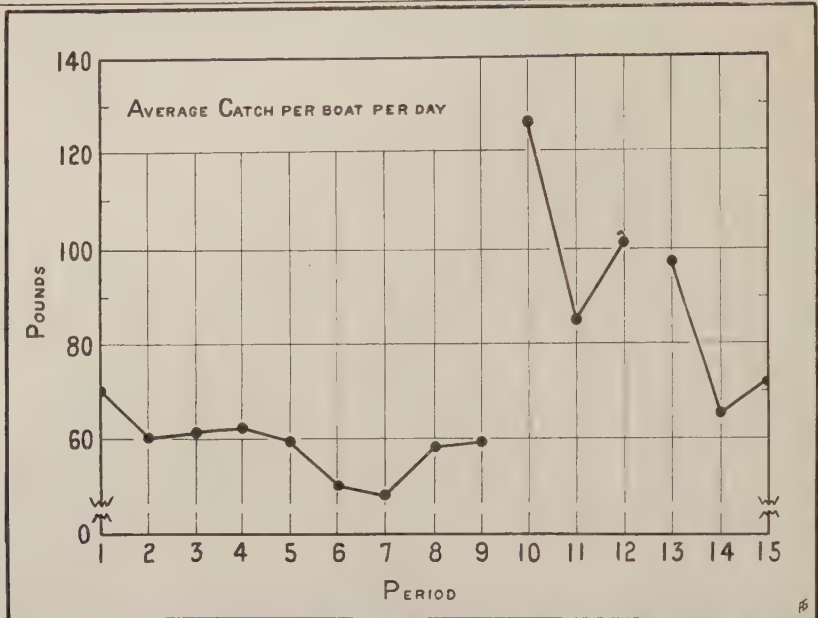


FIG. 10. Average catch per boat per fishing day during each period, derived from entire random sample of data.

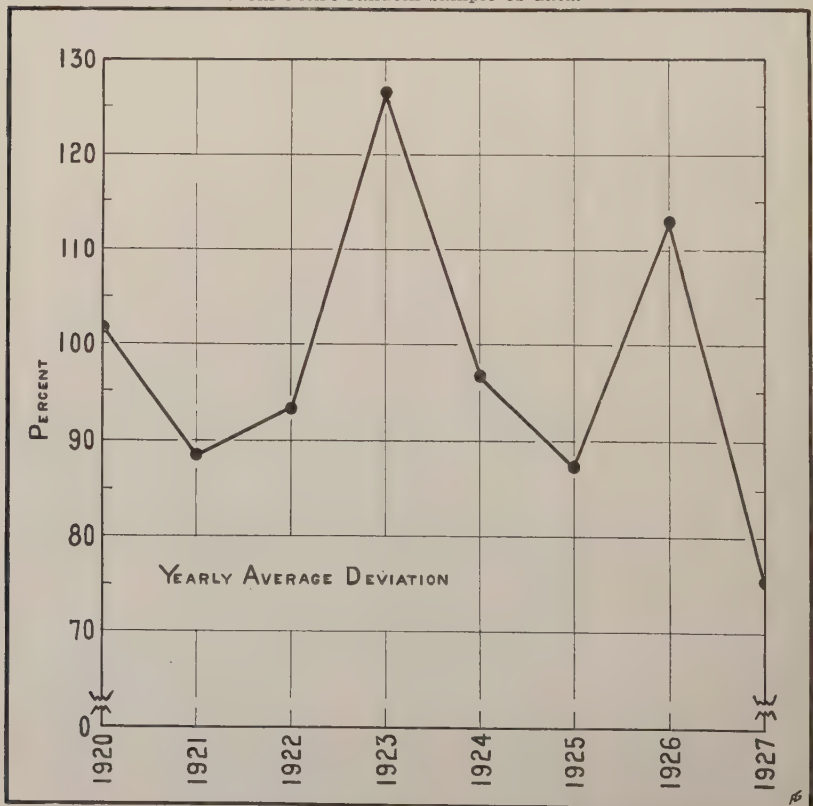


FIG. 11. Average percentage deviation of each year from standard year.

As in the data compiled from the catch records of the twenty boats, the average catch per boat per fishing day is higher during the last six periods of the year than during the first nine. In fact this is more pronounced in the data now under consideration than in the preceding data. Therefore, it appears worth while to apply the method of determining the increase or decrease of each year over the standard year when corresponding seasonal parts are compared.

The method used in this case was identical with that applied to the first data considered. Briefly, it was as follows: First, the average catch per boat per fishing day during each approximately half-month period in each of the eight years represented was changed to logarithms. The logarithmic values for the average catch per boat per fishing day were determined for each period in the base or standard year. The logarithms of the values for each period of the standard year were then subtracted from the logarithms of the corresponding periods in each year. The logarithmic gains and losses of each year's periods as compared to the standard year were then averaged, each

TABLE 9

Year	1920	1921	1922	1923	1924	1925	1926	1927
Percentage deviation from standard year.....	102	89	93	127	97	88	113	76

TABLE 10

Period	1	2	3	4	5	6	7	8
Average daily catch, 1925, in pounds.....	62	53	56	64	50	30	36	31

Period	9	10	11	12	13	14	15
Average daily catch, 1925, in pounds.....	45	144	91	61	184	96	77

period value being weighted by the number of catches made in that period. The values so obtained were changed to their antilogarithms and multiplied by one hundred, the final results being the percentage that each year was of the base year when like seasonal portions were compared.

These yearly averages appear in table 9 and are graphically shown in figure 11.

The only marked change in relative values between the yearly results caused by the procedure outlined above, when average increases or losses were computed for each year after the separate years were compared to like seasonal parts of a standard year, occurred when 1925 fell to a lower value than that obtained for 1921, 1922, or 1924. In the first method employed upon the data now being considered, 1925 had a higher relative position as compared to all of the other years and a higher value than 1921, 1922, or 1924. The two curves are compared in figure 12.

The reason for the lower value of 1925 in the corrected curve is apparent when the period values of 1925 in table 10 are compared to those of the standard year in table 8. The graphic representation of

these values in figure 13 shows that during the first part of the year when the catches are low, 1925 was below normal, while during the latter part of the year when the average catch is normally high the catches of 1925 were above normal. Therefore the average of the proportional increases and decreases of 1925 as compared to the standard year are lower in relation to those of the other years than the arithmetic mean of the catch per boat per fishing day is in relation to the same value for the other years.

This correction appears to be especially applicable to the data being considered, since during periods 6 to 9, inclusive, March 16 to May 16, the bass are present in good numbers, but the size of catch is held down because the shad and salmon are also abundant at that time and that condition causes a division of fishing effort and a lowering of the

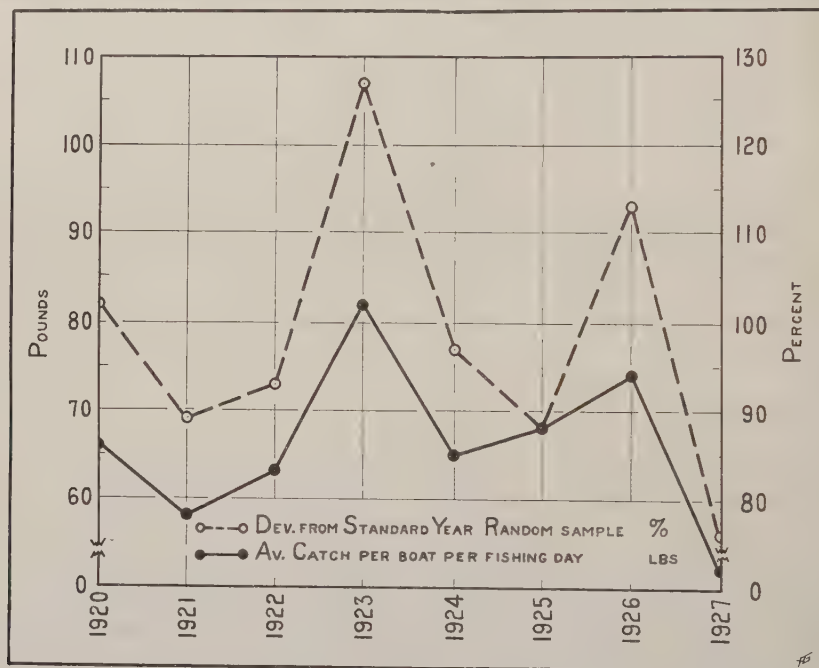


FIG. 12. Comparison of average catch per boat per fishing day during each year and average percentage deviation of each year from the standard year.

average size of daily boat catch. Therefore, while the average size of catch from March 16 to May 16 is not large, the catches represent samples from the fishing grounds taken at a time when a large proportion of the population are present and so they are deserving of more weight than their absolute size in an arithmetic mean for the year procures.

Also, during the last three and first two periods of the calendar year, November 15 to January 31, inclusive, the shad and salmon are not present in any numbers and the weather is such that the bass fishing is not followed as closely as at more favorable times, so that the buyer's boats are usually not on the grounds. The result then is that when the fishermen are making these infrequent trips and have to go farther

to seek their fish, they are more apt to hold a day's catch over and sell two or more days' catches together. This, of course, would cause an artificially high catch whenever it occurred.

Therefore, giving the spring months equal weight with the other months of large average catch in determining the final value for each

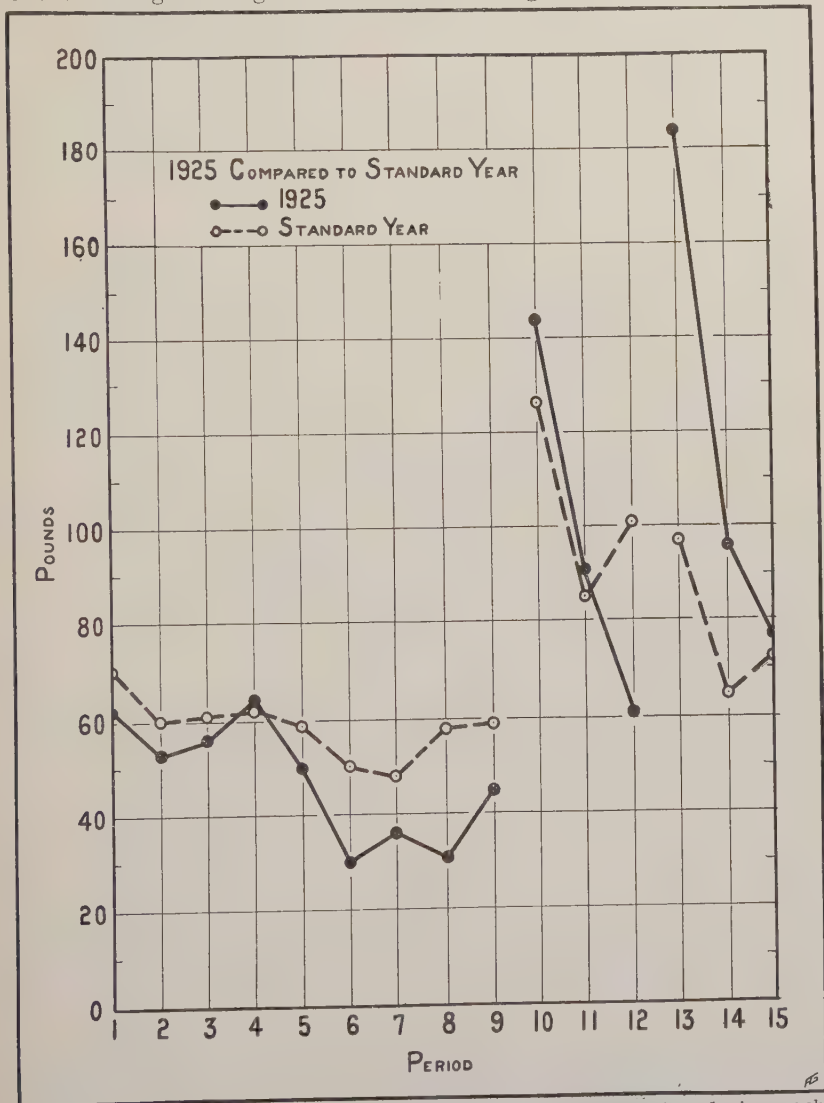


FIG. 13. Comparison of average catch per boat per fishing day during each period in 1925 to the same values of the standard year.

year by the method of computing their proportional increase or decrease as compared to the standard year minimizes these errors, if they occur, and gives the spring months the weight to which they are entitled because of the large proportion of the population which is present on the fishing grounds at that time.

Another correction can be profitably made on the curve shown in figure 9. At times it may happen that the number of catches made in a particular part of the year is much less than the number usually or normally made. This may be due to unusual storms, which make fishing impossible, a strike among the fishermen, or any factor which causes an abnormal curtailment of the number of catches made in the fishery for any appreciable length of time.

When computing the arithmetic mean of the size of catch per fishing day, if such a situation occurs during a season of high catches, the result is a lowering of the yearly average, since fewer than normal large catches will be included. Conversely if it occurs in a season of low catches the yearly average will be high because the usual number of low catches is not present.

Also if the average gain or loss of each year as compared to corresponding parts of a standard year were being computed and the abnormal shortage occurred during periods showing an increase over the standard year, the yearly average would be artificially lowered. While if the lack of catches were in periods falling below the corresponding portion of the standard year, the average yearly increase or decrease would be higher than would be the case if a normal number of catches were present in all periods.

TABLE 11

Period	1	2	3	4	5	6	7	8
Average number of catches per period, 1920-27, inclusive....	202	196	212	223	313	507	638	630
Period	9	10	11	12	13	14	15	
Average number of catches per period, 1920-27, inclusive.....	548	175	147	136	393	271	267	

Therefore, it appeared advantageous to weight corresponding periods by the same value in all years. The values used for this purpose were the average numbers of catches in the respective periods during the eight years represented in the data.

These averages were obtained as follows: The number of catches occurring in period 1 in all of the eight years was determined. This total was then divided by eight, the number of periods represented in this total, the final result being the arithmetic mean of the number of catches included in period 1 in all of the data presented. This procedure was repeated with the data for each of the remaining periods.

From inspection of table 11 it can be seen that the season during which the most catches are made is in periods 6 to 9, inclusive, or from March 16 to May 16, inclusive. This is a season during which the weather conditions are good, and the shad, salmon and bass are all abundant on the fishing grounds. Therefore, the fishing is more intensive then than at other times, although the average catch per boat per day of bass is held to a comparatively low level, because many fishermen are concentrating their efforts on shad and salmon and only take bass incidentally.

The average loss or gain of each year as compared to corresponding periods of the standard year was then computed, each period's deviation from the standard year in all of the years being weighted by the average number of catches for that period shown in table 11. For

example, the logarithmic deviation of period 1 in 1920 was multiplied by the average number of catches for that period, 202, and the deviation of period 2 was multiplied by 196, and so on until the logarithmic deviations of all of the fifteen periods had been multiplied by the corresponding average number of catches shown in table 11. The results of these multiplications were then summed up and divided by the sum of the average number of catches in all of the fifteen periods or 4858. This procedure was repeated with the data for each year,

TABLE 12

Year	1920	1921	1922	1923	1924	1925	1926	1927
Average percentage deviation from standard year, average weighting.....	105	89	92	124	97	86	118	73

the weights for corresponding periods being the same in all years, *i. e.*, the average number of catches for that period as shown in table 11.

The average logarithmic deviations of each year so obtained were then changed to their antilogarithms and multiplied by one hundred, the results being the percentage that the average catch per boat per fishing day during each year is of the catch per boat per fishing day of the standard year when approximately fifteen-day periods of each year are compared to corresponding seasonal parts of the standard

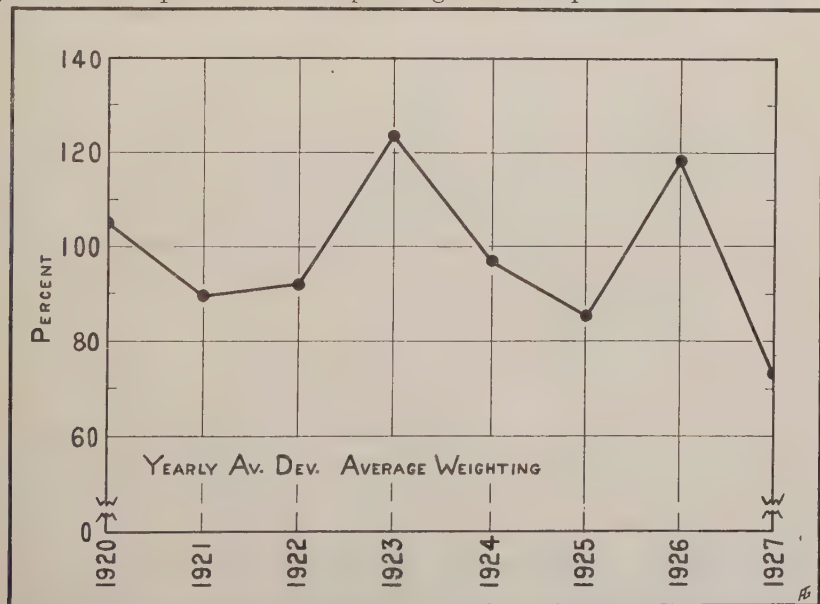


FIG. 14. Average percentage deviation of each year from the standard year. Average weighting.

year. This procedure is identical with that presented on page 16, except that instead of weighting each period in the various years by the number of catches actually occurring in that period the average number of catches for each period shown in table 11 is used for all of the years. Corresponding periods in all years have the same weight in the method now under consideration.

Table 12 and figure 14 show the results of these computations.

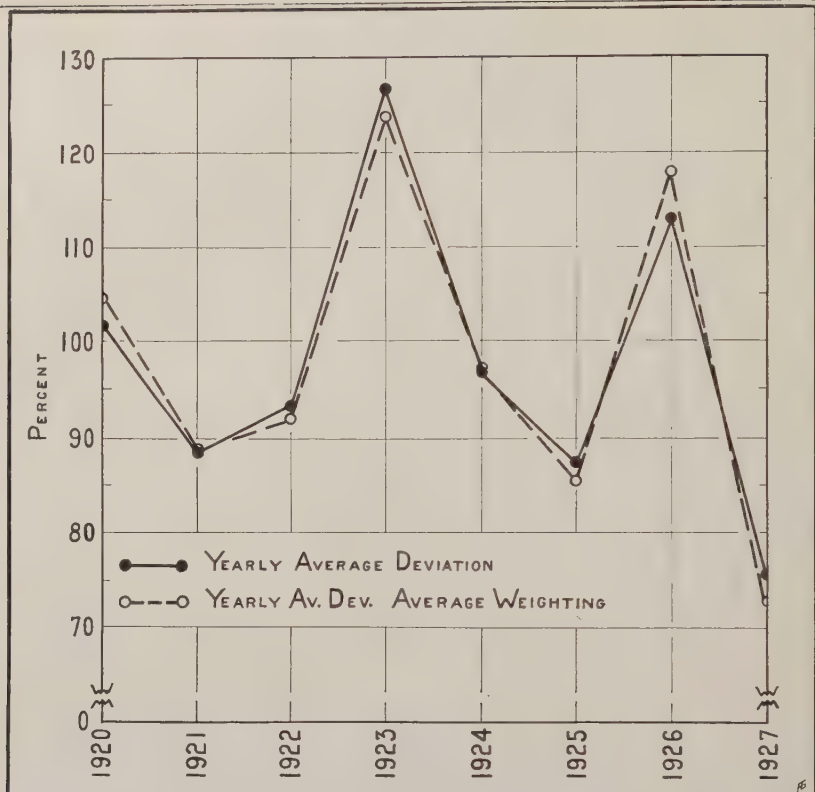


Fig. 15. Average percentage deviation of each year from the standard year. Actual weighting compared to average weighting.

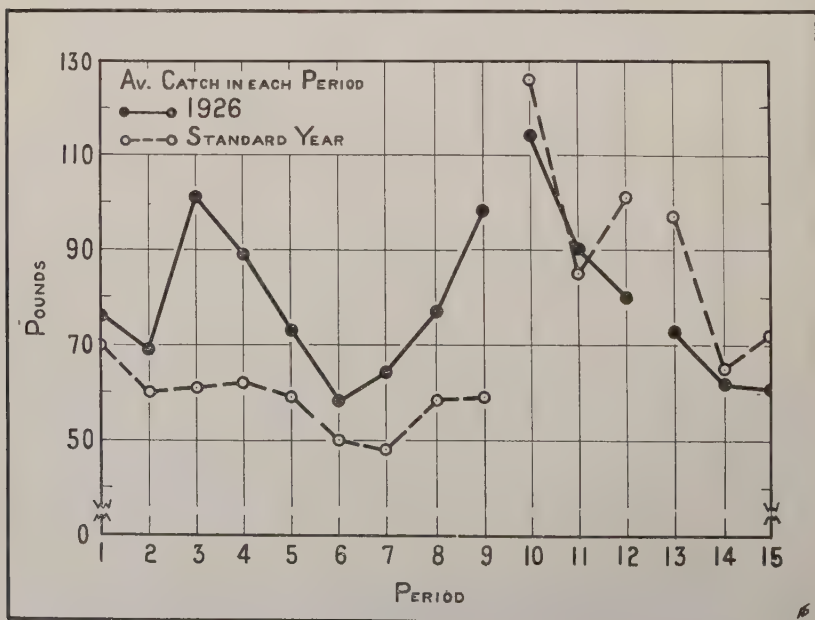


Fig. 16. Average catch per boat per fishing day during 1926 and standard year.

The most striking change caused by the weighting of each period by the average number of catches occurring in that period during the eight years is the increase in the value found for 1926 in relation to the other years.

Figure 15 shows the average weighted curve compared to the actual weighted curve first presented in figure 11 and described on page 23.

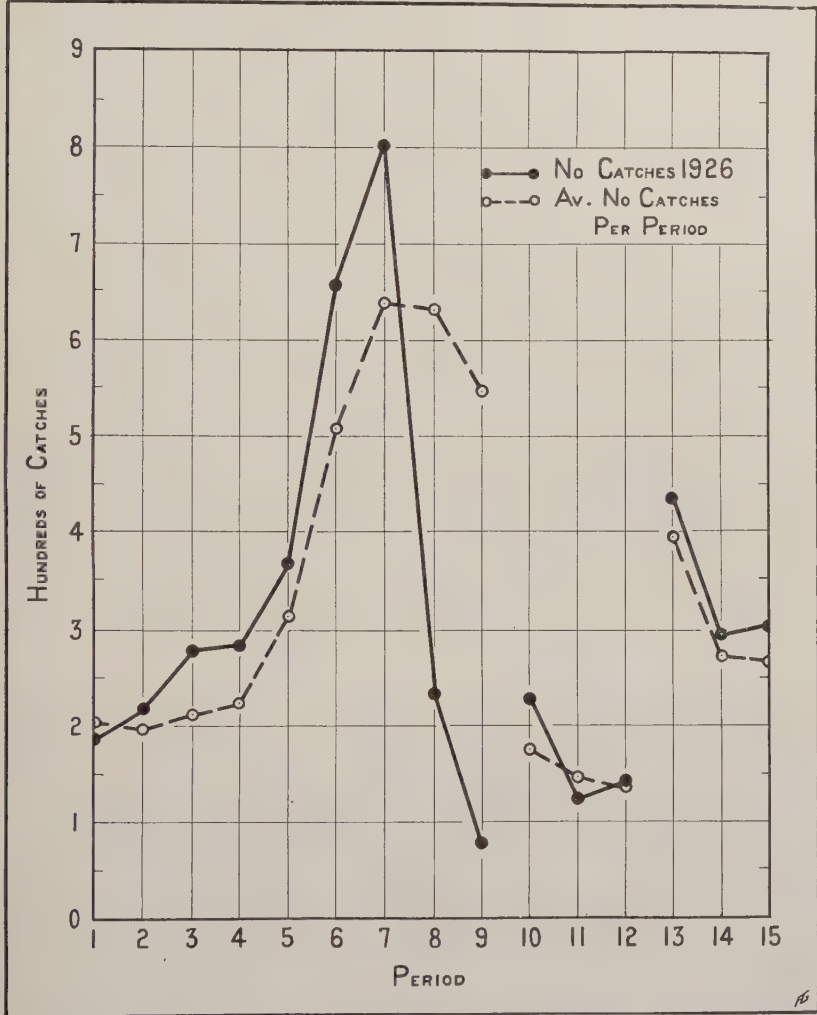


FIG. 17. Number of catches per period in 1926 and average number of catches per period during 1920 to 1927, inclusive.

This increase of 1926 is readily understood by inspection of figures 16 and 17. In these figures it will be noted that during periods 8 and 9, 1926 was well above the average year in size of catch, period 8 being 133 per cent of the same period of the standard year and period 9 being 166 per cent of the corresponding period in the standard year.

Then figure 17 shows that during 1926 only 233 catches were recorded in period 8 as against 630 for the same period in the curve showing

the average number of catches per period during the eight years. Also in period 9 there were 78 catches recorded in 1926, and 548 is the average number of catches for that period.

Therefore, periods 8 and 9 of 1926 received less than the normal weight accorded these periods in the curve where actual number of catches were used in weighting, and since these periods were well above average in size of catch, the result was a lower value for 1926 in the curve in which the period increases and decreases were weighted by the actual number of catches recorded in the respective periods, than in the curve in which average weights were used for each period's gain or loss as compared to the standard year.

The unusually small number of catches made during periods 8 and 9 in 1926 was due to the fact that a strike of the fishermen took place at that time. This strike was brought about by the fact that because of the abundance of striped bass the price paid to the fishermen was lowered to such an extent that they refused to fish. Therefore, since the fish were extremely abundant at that time and since there were enough catches made to supply at least a fairly adequate sample of the catches of that part of the year, it seems logical to give periods 8 and 9 average weights and so more closely approximate the yearly average that would have resulted if the strike had not occurred.

Figure 14, we believe, shows the most reliable yearly index of the abundance of striped bass that can be secured from the second group of data consisting of a random sample of one-half of all of the daily catches of striped bass made in the entire California fishery in the years 1920 to 1927, inclusive.

PART IV

COMPARISON OF RESULTS OBTAINED FROM THE TWO SAMPLES AND CONCLUSIONS

Two samples of data have thus far been considered and from each group a curve has been derived which appears to be the most logical, and which seems to represent most accurately the relative return of catch per constant unit of gear and effort in all of the years for which data were obtainable.

The final, corrected curves from each group of data are shown in figure 18. Upon inspection of these curves it is evident that the curves differ markedly at two points. The curve derived from the data

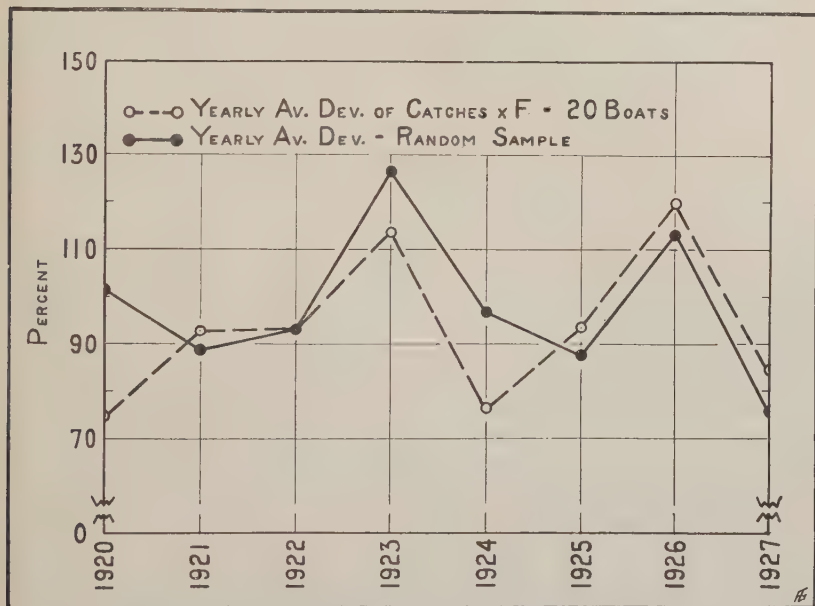


FIG. 18. Comparison of the final curve from the data supplied by the selected sample of 20 boats to the final curve derived from the random sample.

supplied by the catches of the twenty selected boats is lower in 1920 and the value for 1925 has a higher rank in relation to other years than in the curve made from the random sample of every other catch of all of the boats in the entire fishery. There are other minor discrepancies but these two points mark the greatest divergence of trend between the two curves.

That these differences in the corrected curves are due to corresponding divergences in the original data can be determined by consulting figure 19, which indicates the average catch per boat per fishing day during each year as derived from each of the two samples. In this graph it will be noted that the difference in the values for 1925 is even greater in the uncorrected data than in the final curves.

That any differences in the final curves would be due to corresponding differences in the original data would be expected, since both collec-

tions of data were subjected to the same treatment, except that the curve made from the data of the twenty boats was not weighted by average weights for each fifteen-day period as were the data consisting of random samples from all of the boats in the fishery. This procedure was not followed with the data taken from the catches of the twenty boats, because during the time of the strike in 1926, the data from these boats were so scanty that it did not seem advisable to give them any more weight than that to which their actual numbers entitled them in the final results.

Since the difference between the two curves presented are due to corresponding discrepancies in the original data, the question of which curve best represents the abundance or availability of the striped bass to the fishermen can best be determined by considering the adequacy of the two collections of raw data.

As previously stated, the first sample of catch data considered, the final curve from which is shown in figure 5, consisted of the records of

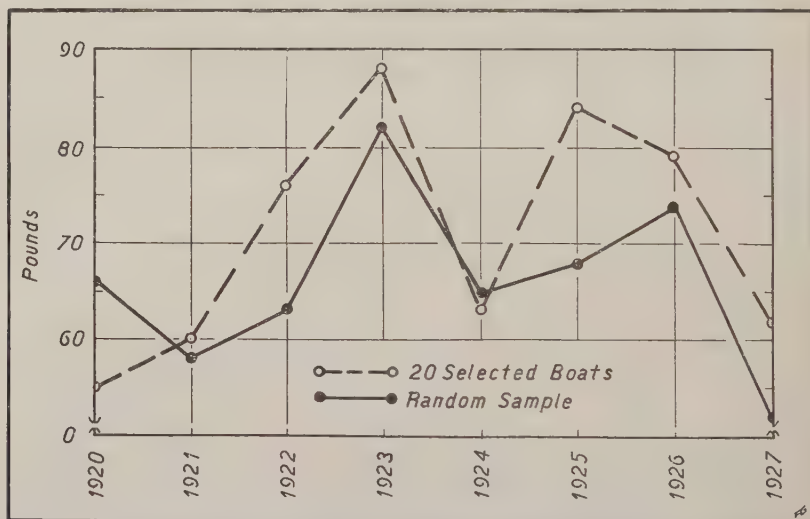


FIG. 19. Average catch per boat per fishing day during each year as computed from the records of the 20 selected boats and the random sample.

daily catches of a selected group of twenty boats. All of these boats furnished continuous records of catch from 1920 to 1927, inclusive, with the exception of three boats that dropped out in 1926. Each of these boats was operated by the same fishermen in every year and, as nearly as could be determined, had approximately the same sort of gear in every year. This selected group of boats then provided a constant unit of fishing gear and personnel.

The other sample of data, from which the final curve shown in figure 14 was derived, was composed of a random sample of every other catch of all boats making catches of striped bass in San Francisco Bay and its tributaries.

The catches recorded in this sample are not the result of the effort of a fixed unit of gear and personnel. However, they do constitute a representative sample during each year of the catches of the entire striped bass fleet, and are therefore indicative of the size of catch

per fishing day per boat as computed from the catches of the boats of the entire fishery.

For several reasons the curve computed from the latter collection of data, consisting of the random sample from the catches of all of the boats in the fishery appears to represent best the relative abundance of the striped bass. First, while as nearly as could be determined, the gear used by the twenty boats was the same during the eight years, all of the nets used by these fishermen were without doubt mended and renewed at different times during the eight years, and some minor improvements may have been made in the gear which would not be recorded on the registration blanks. Such changes would be difficult to detect in individual boats, but if they were widespread enough to affect all or a large proportion of the boats in the fishery, they would be noticed and recorded. While if such changes were restricted to only a few cases they would not affect the random sample. Briefly, the gear used by the whole fishery is more apt to be of a constant character than the gear of a few individuals, and changes in gear widespread enough to affect the whole fishery are more easily detected than changes in the gear of a small number of fishermen.

The selected group of boats was operated by the same fishermen during the period of time covered by this analysis which provides a constant unit of personnel. However, the efficiency of these men may not have remained constant. Some of the men may have become more skillful with added years of experience, and so caused their catches in the later years to be large, or it is possible that some of the men fished with less efficiency as they grew older and were less able to spend long hours on the fishing grounds. These factors would probably average about equally, even in the group of twenty boats, but it seems certain that the average ability of the entire fleet, as represented by the large random sample, would remain constant from year to year.

As has been said before, the men catching striped bass also fish for shad and salmon. The nets used for striped bass are usually of about $5\frac{1}{2}$ -inch mesh, while the salmon nets are composed of much larger mesh, $8\frac{3}{4}$ to 11 inches. Therefore, when the salmon nets are used, only an occasional bass is caught, either a large fish which gills or a smaller one which becomes entangled without being gilled. These accidental catches are always small in total poundage, and if they are at all numerous tend to lower the average catch per day of striped bass. Fortunately, they are not ordinarily very numerous and the fishermen usually catch no bass when using the salmon nets.

The shad fishing, however, exerts a far greater influence on the size of the bass catches. The shad can be taken in the regular $5\frac{1}{2}$ -inch mesh bass net, although at times a net with about $6\frac{1}{4}$ -inch mesh is used. This size mesh will also take numbers of bass although not as many as the regular bass nets. The shad are numerous during a season of the year when the bass are numerous and bass catches are made in large numbers, namely, March, April, and the part of May during which commercial fishing is allowed.

The fact then that the nets used for shad will take bass and that the shad season occurs when the bass are numerous, causes a great many bass catches to be included in the records which have been inversely affected by the shad fishing. The bass catches made when the fishermen

are fishing primarily for shad are below normal chiefly because the bass may not be as numerous in the localities chosen for shad fishing as they are in other places, which would be fished if striped bass were the chief object of the fishing. Also the use of the 6½-inch mesh nets at times by some fishermen undoubtedly lowers the size of the bass catches.

That the fishing for shad does affect inversely the size of the striped bass catches made at the same time was demonstrated as follows: The daily bass catches, made on days when shad were also taken, were tabulated from the catch records of the twenty selected boats, for the months of March, April, and the portion of May open to commercial fishing, during the eight years included in the data. This portion of the season was chosen because the shad are at that time the most abundant. In fact that is the only season of the year during which they are present in the catch in significant numbers. The average

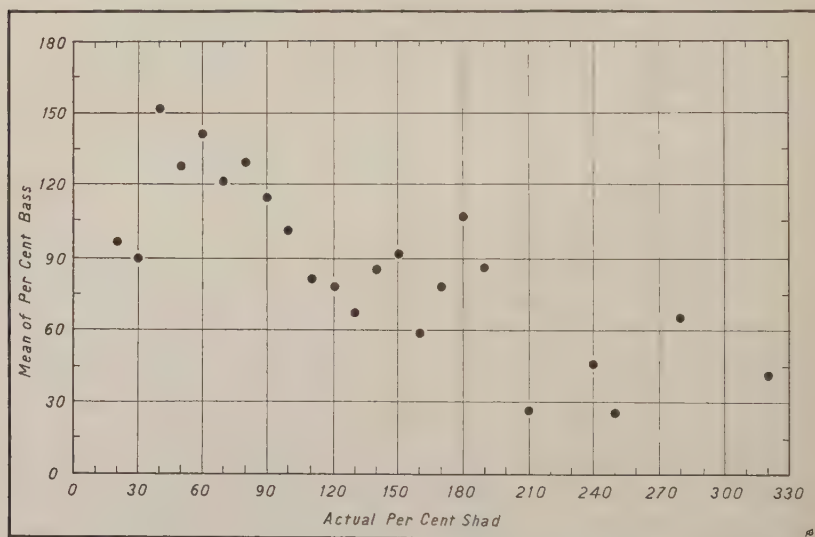


FIG. 20. Relation between percentage deviation of striped bass catches from their means and the same values for the shad catches made on corresponding days.

catch of striped bass per fishing day was then computed for each boat during each year represented in these data. The average catch of striped bass per fishing day during the eight-year period, 1920 to 1927, inclusive, was next determined for each boat. The percentage that the average daily catch of each boat during each year was of its average daily catch during the eight years, was calculated. The percentages resulting from the foregoing procedure are the percentage deviations of the average daily bass catch of each man, as computed from the data included, from the average daily bass catch taken from the same data over the entire period of eight years.

The corresponding shad data were then subjected to the same process.

The final results of these two series of operations are then the percentage deviation for each year of each boat's average daily bass catch, only those catches being used which were made during the months of March, April and May, and on days when shad also were

taken, from the boats' average daily catch computed from the same data over the entire eight years, and the corresponding values for the shad catches made on the same days as the bass catches used.

After securing in this manner the deviations of the yearly averages from their averages of both the shad and bass catches made on the same days for each man for each year, it was possible to demonstrate whether or not there was any relation between the fluctuations about their respective means. In other words with these data, it was possible to determine whether a greater than average daily shad catch during any one year was accompanied by a small or large average daily bass catch during the same period of time when the catches of individual boats were considered.

The percentage deviations in the bass catches were plotted against the corresponding values for the shad catches in a correlation table which is summarized in figure 20, where the averages of the percentage deviations of the striped bass catches in each class interval are plotted against the actual class intervals of the corresponding shad catches. From inspection of this graph, it is evident that as the striped bass catches become less than average in size, the shad catches made on corresponding days tend to be above normal in size.

The Pearsonian coefficient of correlation, r , was computed for these sets of data. The value found for r was $-.43$, with a probable error of $.0470$. The coefficient of correlation, $-.43$, indicates a moderate degree of inverse correlation between the striped bass and shad catches. Also the probable error, $.0470$, proves that the coefficient is significant, since if the coefficient is four times as great as the probable error it is usually considered significant, while in this case the coefficient is more than nine times the probable error.

Evidently, then the average bass catches per year of each fisherman vary inversely with the corresponding averages for the shad catches. This negative correlation we believe to be due to changes in fishing locations and habits when the shad are abundant, which tend to increase the shad catches and decrease the striped bass catches. Therefore, it can be stated that the size of the shad catch inversely affects the size of bass catches when both species are caught at the same time.

A closer degree of correlation would have been found if actual shad and bass catches made on the same days had been used instead of the percentage variations of each from their respective means. It can be plainly seen from inspection of the catch records that boats which consistently make large shad catches make consistently small bass catches during the shad season year after year. However, we previously had corrected for that by raising all boats to a common level in the data of the selected group of twenty boats and by making a seasonal comparison to an average year in both groups of data. Therefore, if the striped bass curves which we have compiled were to be affected by the shad catches, the shad catches would necessarily have to cause some change or be correlated with the fluctuations of the yearly bass averages around their averages for the entire eight years. For that reason the correlation of the percentage deviations of the catches of the two species from their respective means during the eight years was used instead of the actual daily catches or yearly averages of corresponding shad and striped bass catches for each boat.

A small sample of data from a few selected boats will be more liable to be disastrously affected by this influence of the shad fishery than a large random sample from the entire striped bass fleet for the following reasons: If a few of the boats in the selected group changed their fishing habits and concentrated on shad more than was their usual practice, the change in the size of their catches might materially affect the average striped bass catch for that year. They might do this for some reason which would not react upon the whole fleet, or merely because of some personal idiosyncrasy. It would be practically impossible to follow such changes or find the reason for them.

On the other hand in order that the average daily catches for a year as derived from the large random sample should be affected by such a change, the change would have to be general and of such magnitude

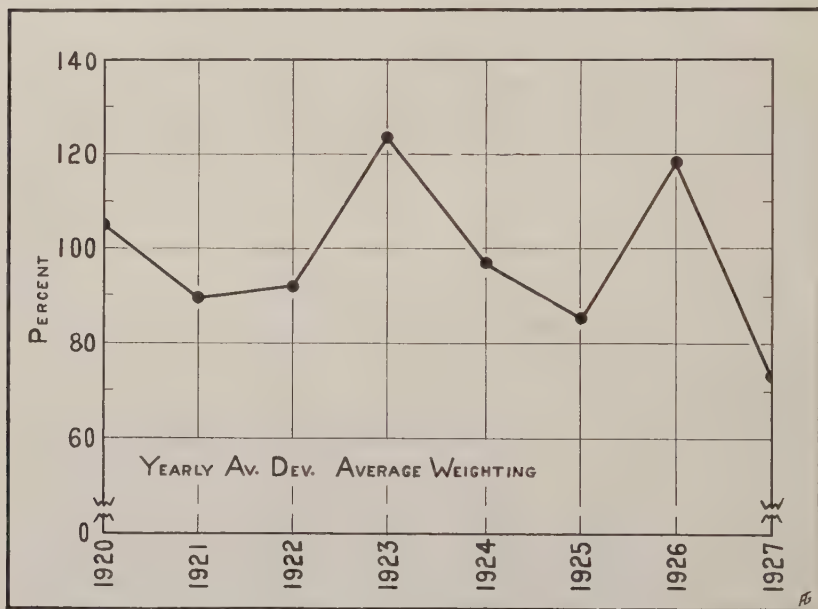


FIG. 21. Average percentage deviation of each year from the standard year. Average weighting.

that it would influence a large proportion of the boats in the entire fishery. Such general changes are far more easily detected and the reasons for them more easily found than the changes in fishing habits of a few individuals.

Besides the fact that the curve derived from the large random sample appears to give a more accurate index of the relative abundance of striped bass during the years represented in the data than the index computed from the data of the selected group of twenty boats, the following facts should also be considered when selecting a method for determining fluctuations in abundance of the species in question. It will be highly desirable in the future to carry this analysis on from year to year, and as time goes on the boats of the selected group will either drop out from the fishery, change owner or gear, or in some other way become undesirable for the analysis, which will necessitate

dropping them from the selected group. After several boats have been discarded from such a group, the analysis must be either discontinued for lack of data or the records of new boats included. If the latter alternative is accepted, the original purpose of keeping the same unit or group of fishing gear and personnel is defeated, and none of the advantages of a large sample of the catches secured. Therefore, it appears that whenever possible a large random sample of catches from a fishery should be used, in order that the analysis may be carried on in the future.

Because of the several above mentioned reasons, the curve shown in figure 14, and again reproduced in figure 21, and which is derived from a sample of daily catches taken from the records of all of the boats in the striped bass fishery, appears to be the best index of the relative yearly abundance or availability of the bass to the fishermen that has been evolved from these data, and it will now be considered in detail.

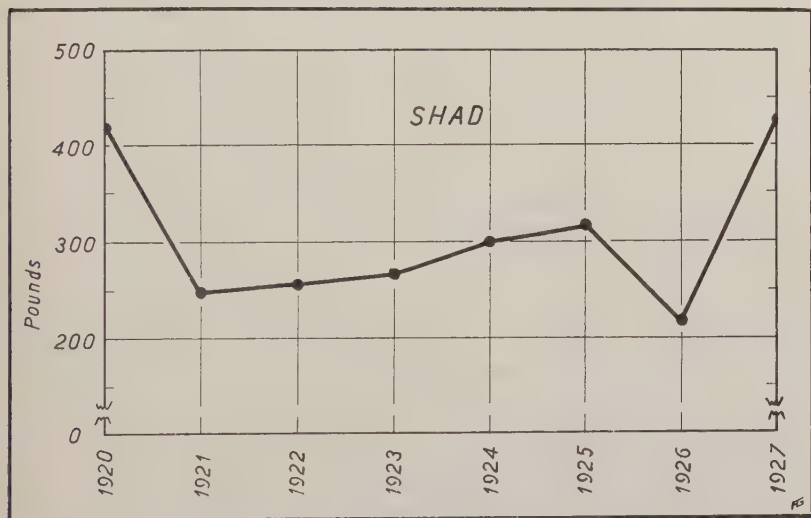


FIG. 22. Average catch of shad per boat per fishing day during years indicated. All boats raised to a common mean by use of factors.

Before attempting to determine what this curve indicates in regard to the relative abundance of bass it might be well to consider what factors other than abundance may have affected its trend. It has been demonstrated previously that the size of the daily catches of shad have an inverse effect upon the magnitude of corresponding bass catches. In figure 22 is presented a curve showing the average catch of shad per boat per fishing day, the data being taken from the catch records of the twenty selected boats.

The yearly averages presented were derived by the same method as that used to compute the values determined for the striped bass catches of the twenty selected boats, except that no seasonal comparison to a standard year was used. Briefly, the average catch per fishing day of each boat during the eight years was computed, and factors were derived from these values by means of which the catches of all boats were raised to an equal mean magnitude. The average catch per boat per fishing day was then determined for each year from all of these data.

No extensive study has been made of the shad fishery and the curve presented may not be an accurate index in detail of the yearly abundance of shad, but without doubt the shad were unusually abundant in 1920 and 1927. It will be remembered that it has been shown that the size of the average catch per unit of effort and gear or abundance of shad has an inverse effect upon the size of the bass catches. Therefore, the abundance of striped bass was somewhat greater in 1920 and 1927 than the index of abundance presented in figure 21 indicates.

The effect of the abundance of shad on the size of the striped bass catch cannot be accurately measured quantitatively from the data at hand, but that it is not great enough to require any major correction in the values for 1920 and 1927 seems certain. In 1920 the bass catch would have been slightly higher if the great abundance of shad had not occurred in that year, and 1927 would have shown a larger return per unit of effort and gear of striped bass if the shad had not been abnormally abundant. However, there was also a real scarcity of bass in 1927, which was probably only made more marked by the abundance of shad.

During the spring and late summer of 1924, fishing conditions were not good for the capture of striped bass, because of unusually low water in the Sacramento and San Joaquin rivers. According to reports of the fishermen and dealers the clarity of the water at that time made the nets more visible than usual, and the fish were wild and did not gill readily during that period. This factor may have lowered the index of abundance artificially to a small extent during 1924.

With these minor corrections taken into consideration, the values presented in the curve shown in figure 21 represent the availability of the striped bass to the fishermen or their relative abundance from 1920 to 1927, inclusive, as accurately as it is possible to derive it from the data available for this analysis.

It will be noted that the curve of abundance is liable to large fluctuations. This probably is due in part to the fact, observed by E. C. Seofield, of the Division of Fish and Game of California, that approximately fifty per cent of the commercial catch of striped bass consists of fish five years of age. This large percentage of fish of one age in the catch is caused by the selectivity of the gill nets used in the fishery, which gill the fish of this particular age and size more readily than the other sizes. Therefore, if there is for any reason a lack or great abundance of five-year-old fish the commercial catch will be greatly influenced by that fluctuation.

The graph under consideration does not show any definite trend. A straight line mathematically fitted to the data will show a downward trend, but because of the large fluctuations and short period of time covered by the analysis, this is not significant. In fact if the value for 1927 were omitted the trend of the line would be slightly upward. Since the value for one year can influence the trend of the entire group of data presented, that trend does not appear to be significant. The logical conclusion appears to be that the curve of abundance does not show any definite trend of either decline or increase, and that as far as may be indicated by it, there are no indications of depletion.

The analysis of the total catch figures also failed to show any indications of depletion. Therefore, as determined from the data at hand, the striped bass fishery appears to have been in a healthy condition during the time covered by this analysis.

The striped bass were evidently placed in a habitat well suited to their needs when they were planted in the waters of San Francisco Bay. They increased with surprising rapidity and have supported a commercial fishery of considerable proportions for some forty years without apparent injury to the supply.

If all conditions affecting the striped bass continued to remain the same the striped bass population could continue to support this fishery without injury to the supply.

However, some conditions affecting the striped bass are changing. One of these changes is the great increase in sport fishing for the striped bass, which has taken place in the last ten years. Unfortunately, no data on amount of fish caught by sportsmen have ever been collected, but that angling for striped bass has increased enormously in the last few years is readily admitted by most sporting goods dealers and sportsmen. This increase in the catch of pleasure anglers may cause a considerable added strain on the striped bass supply.

Also during the last twenty years, many acres of overflow lands have been reclaimed along the Sacramento and San Joaquin rivers. These areas when flooded may have offered good spawning grounds or abundant food supply for the striped bass, and their reclamation may react against the welfare of the striped bass population by removing some of its desirable habitat.

Therefore, while there is no evidence of depletion apparent up to 1927, and the striped bass supply seems well able to support its commercial fishery as long as other conditions remain constant, it would be well to carry on the study of the fluctuations in abundance of the striped bass from year to year in order that the effect of any factor which might dangerously diminish the striped bass supply might be detected.

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